March 24, 1953

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2,632,631

DRILLING MUD FLOW SYSTEM

Filed May 6, 1949

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FIG. 2.

FIG. 3.

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3 Sheets-Sheet 3

FIG. 4.

FIG. 5.

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DRILLING MUD FLOW SYSTEM

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Application May 6, 1949, Serial No. 91,798

4 Claims. (Cl. 255—13)

1. The present invention relates to earth boring operations. More particularly the invention is directed to a method and to apparatus for controlling flow of a fluid drilling mud during the drilling of deep wells.

As the drilling of wells has developed to deeper and deeper horizons beneath the surface of the earth, it has become more and more important that the drill operator should have complete control of the pumping of drilling fluid downward into the borehole.

In the course of drilling operations, it is often necessary to stop circulation of drilling mud in order to change drill bits, to lengthen the drill stem, or to make measurements in the borehole. Because the pump pressures involved are quite high, sometimes reaching several thousand pounds per square inch, and because of the abrasive nature of the drilling mud, it has heretofore been the practice to stop circulation of mud by shutting off the driving power for the pumps thereby completely stopping the pumps and mud circulation.

While this method of stopping circulation has been almost universally employed in rotary drilling operations, it has not been entirely satisfactory primarily for the reason that the mud pumps often lose their prime and fail to regain suction when restarted. Occasionally when suction is suddenly regained, the pumps build up tremendous pressures which may blow out protective relief valves or may even break pump lines or the pump mechanism itself. Regardless of causes and effects, experience has shown that much time which could be spent in advancing the drill bit into the earth is lost as a result of the practice of stopping and starting mud pumps.

We have now devised a method and apparatus whereby this needless loss of time has been greatly reduced. Briefly stated, the method of our invention contemplates continual driving of the mud pumps so that drilling fluid is continually pumped therethrough. During normal drilling operations when it is desirable to inject drilling mud into the well bore, the mud pumps are operated at a normal speed and the drilling mud is forced under pressure through a conventional feed line, stand pipe, and drill stem, and thence upwardly through the well bore and back to the mud reservoir. When it becomes necessary to stop injection of drilling mud into the well, the speed of operation of the mud pumps is first reduced from normal operating speed to a low idling speed such that the pressure head developed thereby may be insufficient to overcome the hydraulic head of fluid in the standpipe. Thereafter a release valve is opened permitting the mud from the pump outlet or mud feed line to return directly to the mud reservoir through a by-pass line or path which excludes the drill stem and well bore. In accordance with the practice of our invention, the mud pumps are not stopped except for repairs or servicing of the pumps. Furthermore, fluid passage from the pumps through the feed line and standpipe and thence to the drill stem is never blocked off as by the closing of a valve. When it is desired to resume mud circulation to the borehole, the mud release valve is closed while the pumps are operating at idling speed; the speed of the pumps, and the consequent pressure head developed thereby, is then increased to a desired operating value.

While the method of our invention may be practiced by manual manipulation of apparatus elements in proper sequence, we prefer to conduct certain of the steps automatically and preferably by remote control. Accordingly, our invention also includes a combination of apparatus elements whereby the circulation of fluid mud into a borehole may be started or stopped from a single location, such as from the derrick floor which may be remote from the mud pumps.

The method and apparatus of our invention may be best understood by reference to the accompanying drawings in which:

Figure 1 is a perspective view showing the location of various apparatus elements which may be employed in practicing one embodiment of our invention. Figure 1 is not drawn to scale and no attempt has been made to show all of the connecting conduits employed in the control mechanism of our invention. Figure 1 is intended to illustrate an appropriate location of major control elements shown in Figures 2 and 3;

Figure 2 is a diagrammatic flow sheet of one embodiment of apparatus, including connecting conduits, suitable for the practice of our invention;

Figure 3 is a diagrammatic flow sheet of another embodiment of apparatus providing flexible control of a plurality of pumps in accordance with our invention;

Figure 4 is an elevation view, partly in section, of a pneumatically operated mud release valve adapted to be used in the practice of our invention; and

Figure 5 is an elevation view, partly in section, of another mud release valve which may be opened pneumatically and be caused to close by spring action.

In the accompanying drawings and in the following description, it is assumed for purposes of illustration that the mud pumps are steam driven reciprocating pumps. However it will be apparent to workers skilled in the art that the method of our invention may be readily applied to other types of pumps and to other types of power for actuating these pumps by minor modif-
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Referring first to Figure 1, it will be observed that numeral 14 designates a conventional well drilling derrick structure having a floor 12. The floor 12, in
usual practice, is generally elevated about 10 or 15 feet above the surface of the earth. Centrally located in the floor of the derrick is a rotary
table 15 which is employed to rotate a tubular kelly joint 16 upon the lower end of which is affixed a suitable length of tubular drill pipe 18. Kelly joint 16 and drill pipe 18 collectively may be said to constitute a drill stem on the lower end of which is fixed a conventional rotary drill bit (not shown).

Suspended by cables 16 from a crown block at the top of derrick 11 is a travelling block 17, carrying an elevator hook 18 and a conventional swivel joint 19. Swivel joint 18 is connected to kelly 16 and provides means whereby drilling fluid introduced therein through flexible mud hose 20 may be forced downward through the drill stem. Mud hose 20 is connected to the upper end of a standpipe 21 which generally is supported by one leg of conventional drilling practice standpipe 21 extends in
direction from floor 12 to approximately one-half the height of the derrick. A mud feed pipe 22 is connected to the bottom end of standpipe 21 and is, generally, manifolded to the outlets of a plurality of mud pumps 23. Although in some installations pipe 22 may be connected to the outlet of a single pump. Pump means 23 are commonly located at an elevation below the lower end of standpipe 21 and adjacent a mud reservoir or pit 24 which may be an earthen pit arranged at any convenient location near the derrick 11. In marine drilling operations, mud reservoir 24 may be a tank suitably arranged on a barge or other support adjacent the
derrick, and mud feed pipe 22, in this instance, may include a suitable flexible section.

In Figure 1, numeral 25 designates suction lines which may be manifolded as desired, connecting the inlet ports thereof with mud reservoir 24. Each pump is preferably provided with actuating means such as, for example, a reciprocating stem. According to the present invention, the mud in the well bore is admitted directly to pump means 23 through branch lines 26a and 26b. It will be understood that this showing represents the general connection of the steam lines to suitable means for actuating the respective pumps.

In the conventional operation of a well drilling rig, as thus far described with reference to Figure 1, drilling mud is withdrawn from reservoir 24 by pump means 23 and is forced thereby through mud feed pipe 22, standpipe 21, mud hose 20, swivel joint 19, kelly 16 and drill pipe 15 into the earth borehole. After passing out of the drill bit on the lower end of the drill pipe, the mud passes upward through the borehole into surface casing. Figure 1, numeral 27 designates the
door and ultimately passes into mud return pipe 27 from whence it is discharged into a shaker 28 or other means for separating drill cuttings from the mud. The recovered mud is then returned to reservoir 24 through a suit-
able conduit, such as mud ditch 29.

The methods and apparatus thus far described is old and conventional in the art. In accordance with our invention, we provide a conduit

which may branch from feed pipe 22 at any unobstructed position between the outlet of pump means 23 and the base of standpipe 21. Conduit 30 is preferably arranged to spill drilling fluid into reservoir 24. At any desired position in conduit 30, and conveniently on the outer end thereof, we provide a mud release valve 31. However, we prefer to block fluid communica-
tion between feed line 22 and standpipe 21, as by a manually arranged valve, as at any position between the outlets of pump means 23 and standpipe 21.

In accordance with our invention, we also provide one or more throttling valves 32a and 32b either in steam header 16 or in branch line 26a and 26b. When pump means 23 are other than steam operated, it will be apparent that throttling valves 32a and 32b will be replaced by other equivalent means adapted for use with the particular type of power employed and capable of throttling the speed of pumps 23. Throttling valves 32a and 32b may be manually controlled valves, in a preferred embodiment of our invention, these valves are remotely controllable in proper sequence from a single station such as by controlling other drilling controls above the derrick floor. Suitably, controller 33 may operate valves 32a and 32b by varying fluid pressures applied to actuating mechanisms thereof. If desired, however, controller 33 may operate valves 32a and 32b by varying mechanical linkages or by electrical actuating means.

When it is not desired to employ the remote control feature of our invention, valve 31 and throttling means 32a and 32b are individually controlled by manual adjustment. During normal operations when drilling mud is injected into the well bore, valve 31 is fully closed and throttling means 32a and 32b are each adjusted so that pumps 23 operate at a normal speed and develop a sufficient pressure to force drilling mud through the conventional circuit hereinbefore described. When it is desired to pump the injection of mud into the well bore, throttling means 32a and 32b are each manually closed far enough to reduce the speed of operation of pumps 23 to a low idling speed without stopping them. Throttling valves 32a and 32b are manually valved to any permitting the mud passing through the pumps to return directly back to mud pit 34. If kelly 16 is now disconnected from drill pipe 15, as, for example, to permit insertion of an additional stand of drill pipe, it will be found that drilling mud standing in kelly 14 will syphon back to reservoir 24 through stand pipe 21, feed line 22, by-pass line 30 and valve 31.

Throttling means 32a and 32b are maintained at the idling speed adjustment described above and valve 31 is maintained open at all times when it is not desired to inject mud into the borehole. When it becomes desirable to resume injection of mud into the well bore, valve 31 is first manually closed and throttling means 32a and 32b are thereafter opened until pumps 23 are preferably arranged to spill drilling fluid into reservoir 24. At any desired position in conduit 30, and conveniently on the outer end thereof, we provide a mud release valve 31. However, we prefer to block fluid communica-
tion between feed line 22 and standpipe 21, as by a manually arranged valve, as at any position between the outlets of pump means 23 and standpipe 21.

Turning now to Figure 2, a combination of pneumatic elements adapted to control the operation of valves 31 and 32a will be described. In Figure 2, the controller 33 may be a dual-control, air valve of a type commonly employed in the actuation of the air brakes of vehicles. Details of the controller 33 will not be described herein since this structure is well known in the pneumatic controller art and is typically illustrated by the Type B “Flexair” pressure con-
control valve manufactured by Westinghouse Air Brake Company of Wilmerding, Pennsylvania. In substance, the piping system comprises two independently operated piston valves adapted to regulate the pressure of a compressed gas, such as compressed air supplied from a source (not shown) through pipe 34, and to deliver a constant pressure into either pipe 33 or pipe 35. When the valve of controller 33 is in the position designated 32a, air is exhausted to the atmosphere and supply pipe 34 is blocked. On the other hand, when the handle of controller 33 is moved toward a position indicated by either 32b or 32c, a controlled pressure is delivered either into pipe 35 or pipe 33, respectively. While conducting operations in accordance with our method, controller 33 is rarely operated in the intermediate position but is set in this position only when it is desired to stop completely the operation of pump means 23.

The pipe 35 is connected to deliver pneumatic pressure to the diaphragm chamber of a diaphragm actuated, spring return, four-way valve 37. The structure of valve 37 is well known in the art and may be illustrated by the four-way, single diaphragm operated valve manufactured by the Goodyear Akron, Ohio. Valve 31 is arranged so that, when pressure is applied to the diaphragm chamber through pipe 35, the diaphragm is depressed and opens passages in the valve to permit transmission of compressed gas from pipe 34 into a pipe 38 and simultaneously to exhaust the atmosphere to the compressed gas in a pipe 35. When pressure is removed from the diaphragm chamber of valve 37, the spring return thereof moves the valve element so that pressure in pipe 35 is vented to the atmosphere and pressure in pipe 34 is transmitted into pipe 35. In accordance with a preferred form of our invention pipes 35 and 33 are connected to cylinders on opposite sides of a piston of mud release valve 31 in a manner which will be described more fully in connection with Figure 4. Application of positive pneumatic pressure in pipe 35 causes valve 31 to open while application of pressure in pipe 33 causes valve 31 to close. So that a predetermined delay between the pneumatic actuation of diaphragm valve 37 and the opening of valve 31 may occur, a speed control valve 40 is preferably arranged in pipe 33 between valves 31 and 37. Speed control valve 40 may be a conventional speed control comprising needle and check valves offering resistance to flow in the direction from valve 31 to valve 31 but little or no resistance to flow in the opposite direction.

As shown in the drawing, pipe 35 is also connected through a branch pipe 41 to a piston-type, two-way check valve 42 and thence by pipe 43 to the diaphragm chamber of a diaphragm operated, spring return, valve 26a or 26b. Valve 32a is normally closed when no pneumatic pressure is applied to the diaphragm chamber thereof. So that pump means 25 will operate only at a low idling speed when controller 33 is in the position indicated by 32a, a speed regulator 44 is arranged in line 41. Speed regulator 44 is connected by line 45 to a control orifice reducing valve capable of maintaining a predetermined pressure differential between the supply and delivery pressures. Preferably the pressure differential should be conveniently adjustable to within desired limits. Regulator 44 is adjusted to reduce the pneumatic pressure to such an extent that valve 32a will open only part way when full pneumatic pressure is delivered into pipe 35.

It is to be noted that, with the operating handle of controller 33 in the position designated 32a, pipe 36 is vented to the atmosphere. In this position, the piston or plunger of dual check valve 45 takes up a position to prevent flow of compressed gas from pipe 41 to pipe 36.

When the handle of controller 33 is moved from position 32a to position 32b, pressures in pipes 35 and 41 are vented to the atmosphere and substantially the full pneumatic pressure from line 34 may be delivered to the diaphragm chamber of valve 32a thereby fully opening this valve and permitting pumping means 23 to operate at full speed. A speed control valve 45, substantially identical to valve 40, is preferably included in pipe 36 between controller 33 and check valve 42 in order to delay the opening of valve 32a subsequent to actuation of valve 31.

Figure 3 illustrates a preferred combination of elements particularly adapted to control the flow of drilling fluid when pumping means 23 comprises two or more pumps operat- ing in parallel or in series. In the embodiment shown in Figure 3, the dual controller 33 and 33' of Figure 2 is replaced by a similar controller 33' having a single pneumatic valve which is actuated by movement of the control handle from the position 33a toward the position indicated by the broken line 33'b. Compressed gas is supplied from a source (not shown) through pipe 34. The pressure of the gas passing through controller 33' is regulated in accordance with movement of the control handle and is transmitted through pipe 35 to the diaphragm chamber of four-way valve 37. Valve 37 may be identical to the valve 37 of Figure 2 and serves a function similar thereto.

Pipes 36 and 38 connect valve 37 to mud release valve 31 in a manner similar to that shown in Figure 3. However, pipe 38 does not include the speed control valve 45. Furthermore, pipe 38 is branched and connects to a pipe 45 which leads to one side of dual check valve 42. A speed control valve 45 and a regulating relief valve 47 are arranged in line 46 to provide adjustable delay action and over-all speed regulation, respectively.

The mechanism of regulating valve 47 is similar to that of controller 33' but, for operating convenience, instead of having a toggle-type actuating lever, valve 47 preferably has a rotating handle adapted to be set and locked in a desired position. As will be seen from Figure 3, the pipe 41 branches from pipe 35, delivers into dual check valve 42 and from thence into pipe 43. Pipe 43 is preferably branched into a plurality of pipes 43a, 43b, etc, which connect to the diaphragm chambers of valves 32a, 32b, etc, arranged in steam lines 26a, 26b, etc. So that the speed of each of the plurality of pumps in pump means 23 may be individually adjusted, regulating valves 42a and 42b are preferably installed in pipes 43a and 43b, respectively. Valves 42a and 42b may be substantially identical to valve 41.

In a practical installation of the combination of apparatus shown in Figure 3, diaphragm valve 37, dual check valve 42, speed control valve 45, and regulating valve 47 may be conveniently installed upon a control board operating with controller 33. Mud release valve 31 may be installed at some distance from controller 33' and preferably adjacent mud reservoir 24. Likewise, diaphragm valves 32a and 32b and individual pump regulating valves 42a and 42b are preferably installed adjacent pump means 23.
which may be a considerable distance from control-

controller 33'. Under these conditions, it is desirable to provide on the aforementioned control board a plurality of block valves 48a and 48b in pipes 43a and 43b, respectively, so that any one of the plurality of pumps may be put out of service as desired. Also, since pipes 43a and 43b may be of considerable length, it is desirable that there be installed in each of these lines adjacent the diaphragm chambers of each of valves 32a and 32b quick release valves such as 58c and 58d. Quick release valves 58c and 58d are well known in the pneumatic control art and may consist of a diaphragm so arranged that, when pneumatic pressure is applied to one side of the diaphragm, an exhaust port is closed before compressed gas is delivered to a chamber, such as the diaphragm chamber of valve 32a. When the pneumatic pressure applied to the diaphragm of the quick release valve is reduced below a predetermined value, the diaphragm is pressed by a spring to close the supply port and open an exhaust pas-
sage from the aforementioned chamber to the at-
mosphere. Thus, the chamber may be more quickly exhausted than it would be if the exhaust path for the chamber were through a long length of pipe. In the embodiment of Figure 3, valves 56a and 56b permit valves 32a and 32b to close quickly in response to a reduction in supply pres-
sure caused by regulation of valve 33' or valve 47. Operation of the system illustrated in Figure 3 is as follows:

When it is desired to stop circulation of mud to standpipe 21, the handle of controller 33' is moved from the normal operating position 33'b to the position 33'a. Pneumatic pressure in the pipes 35 and 41 is thereby vented to the atmos-
phere causing the mechanism of valve 37 to move into a position whereby full supply pressure from pipe 34 is transmitted into pipes 36 and 46. The pressure in pipe 46 is transmitted through speed control 45 to idling speed regulator 47, thence through dual check valve 42 to pipe 43 and sub-
sequently to the diaphragm chambers of valves 32a and 32b. Since regulator 47 is used as a master control of pump idling speed, the pneu-
matic pressure is reduced in this valve and, be-
cause of the presence of quick-release valves 59c and 59d in lines 43a and 43b, diaphragm valves 32a and 32b quickly operate to supply only suffi-
cient steam to the pumps to operate them at an idling speed.

Substantially simultaneously with the above-
described operations, pneumatic pressure in pipe 39 is vented to the atmosphere through valve 37 and pressure in pipe 38 is transmitted to valve 31 causing the latter to open and by-pass mud from the outlet of pump means 23 to reservoir 24.

When it is desired to resume circulation of mud to standpipe 21, the handle of controller 33' is moved from the position 33'a toward the position 33'b. Such movement of pump idling pressure to be admitted into pipes 35 and 41 and the diaphragm chamber of valve 37. The mechanism of valve 37 thereupon moves to a position where-
by pressure is quickly vented from pipes 38 and 46. Simultaneously with the venting of pipes 38 and 46, pressure is transmitted from pipe 34 through valve 37 into pipe 35 and thereby pressures valve 31. Also pressure in pipe 41 causes the plunger in check valve 42 to move and thereby transmit pressure from pipe 41 into pipe 43 and thence to the diaphragm chambers of valves 32a and 32b.
cap member 59 thereby pulling piston-like member 63 out of sealing relation with ring 64. Thereupon mud fluid passing through nipple 51 and out through openings 60. Upon exhausting pneumatic pressure from the portion of chamber 58 defined between wall 56 and piston 66, as by exhausting pneumatic fluid through line 38, the release of mud through openings 60 may be stopped by applying pneumatic pressure through line 39 and opening 61 to piston 74. Application of this pressure causes piston 74 to move away from cap 59 and toward wall member 55. Piston 66, shaft 62 and member 63 move with piston 66 until member 63 is brought into sealing contact with ring 64 and the valve is thus closed. After the valve is closed and fluid pressure has built up within nipple 51, pneumatic fluid may be exhausted through pipe 39 without permitting the valve to open since mud fluid pressure is transmitted through passage 73 into the portion of chamber 58 between pistons 66 and 74. However, when sufficient pneumatic pressure is again introduced through pipe 38, any mud fluid entrapped between pistons 66 and 74 flows back through passage 73 and permits the valve to open.

Turning now to Figure 5, a self-closing valve is shown which is somewhat similar to the valve described with reference to Figure 4. The valve shown in Figure 5 differs from that shown in Figure 4 in the respect that a spring 82 performs the basic function of piston 14. As will be seen from the drawing, one end of helical spring 82 bears against piston 66 and urges the latter toward wall member 55. The opposite end of spring 82 bears against a cap 95 which may be threadedly engaged on body member 54. Cap 95 contains an opening, equivalent to the opening 61 shown in Figure 4. A tubular member 83, having openings 84, is screwed threadedly engaged upon the end of shaft 62 in place of the nut 67 in order to hold piston 66 upon the shaft and also to serve as a guide for spring 82 and minimize non-helical distortion thereof during compression. Openings 84 permit mud fluid to enter chamber 58 between piston 66 and cap 95.

When a valve of the type shown in Figure 5 is employed in one of the systems described in connection herewith, the operation may be simplified by omitting pipe 39 and by substituting a three-way valve in place of the four-way valve 37.

Although our invention has been described and illustrated by reference to specific embodiments thereof, it will be apparent to workers skilled in the art that various modifications and substitutions of equivalents may be made without departing from the scope and spirit of the appended claims.

We claim:

1. In a system for circulating fluid mud in earth boring operations including a mud reservoir, pump means having an inlet and an outlet and adapted to pump fluid mud, driving means operatively connected to said pump for actuating the latter, means connecting the inlet of said pump to said reservoir, and a mud feed pipe connecting the outlet of said pump to the base of a standpipe elevated above the pump, the improvement which comprises, in combination, a conduit branched from said feed pipe and capable of discharging fluid mud from the outlet of said pump into said reservoir, a release valve in said conduit interposed between said feed pipe and said reservoir, throttling means and adapted to control actuation of said pump, and a control means operatively connected to both said release valve and said throttling means for sequential operation thereof, said control means being adapted to close partially said throttling means and then to close fully said release valve and also being adapted to close fully said release valve and then to open said throttling means.

2. A system in accordance with claim 1 in which said release valve and said throttling means each include actuating means responsive to changes in pressure of a fluid and said control means includes a master valve for altering fluid pressures applied to said actuating means.

3. A system for controlling fluid mud circulation to a borehole in the earth comprising, in combination, a mud reservoir, a pump having an inlet and an outlet and adapted to pump mud, driving means for driving said pump, throttling means for controlling the speed of said driving means, means for conducting mud from said reservoir into said pump, said pump and said conduit being in combination, a conduit branched from said feed pipe and capable of discharging fluid mud from the outlet of said pump, a release valve in said conduit interposed between said feed pipe and said reservoir, and a control means operatively connected to both said release valve and said throttling means for sequential operation thereof, said control means being adapted to cause partial closing of said throttling means and then full opening of said release valve and also to cause subsequent full closing of the release valve before opening the throttling means.

4. In the drilling of wells in the earth wherein drilling fluid is injected into a well bore from a pool of drilling fluid in a normal path of flow during selected periods of time and wherein injection of drilling fluid through said normal path of flow is interrupted during other periods of time, the method of continuing flow of drilling fluid which comprises injection drilling fluid into the well bore at a selected rate of flow and returning the drilling fluid from the well bore to said pool during said selected period of time through the normal path of flow, substantially reducing the rate of flow of drilling fluid, establishing a path of flow for said drilling fluid separate from and excluding a major portion of the normal path of flow, and returning the drilling fluid at the reduced rate of flow to said pool through said separate path of flow during said other periods of time.

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